Obscuration and circumnuclear medium in nearby and distant AGN

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Abstract. Some recent results on the physical and statistical properties of nearby and distant AGN are presented. I first discuss the properties of “elusive” AGNs, i.e. obscured AGNs which do not show a Seyfert-like spectrum in the optical. Then I present preliminary results from a detailed study of the contribution of obscured AGNs and of their host galaxies to the infrared cosmic background. Finally I discuss an observational program aimed at investigating the properties of the most distant quasars, of their circumnuclear medium and the implications for their host galaxies.

1 Introduction

Obscured Active Galactic Nuclei (type 2 AGNs) have been investigated in great detail in the local universe. The recent deep surveys have also found several obscured AGN at high and intermediate redshift, and have shed new light on their evolution [12]. However, there are still some open issues on the physical and statistical properties of obscured AGNs. There is growing evidence for a population of obscured AGNs which do not show the classical AGN signatures in their optical spectra, which might require a revision of the unified model as well as reassessment of the density of AGNs in the local universe. At higher redshift it is now clear that a mixture of obscured and unobscured AGN produce most of the X-ray background, but it is much less clear what is their contribution to the IR background and the possible connection with the evolution of galaxies. At the highest redshift ($z \sim 6$) probed so far by quasar surveys, it is not clear what are the properties of the circumnuclear medium and, specifically, if the gas has the requirements to produce obscuration, both in terms of metallicity and dust content. In this paper I shortly summarize some recent work aimed at tackling these issues.

2 Elusive AGNs

A fraction of active galactic nuclei do not show the classical Seyfert-type signatures in their optical spectra, i.e. they are optically “elusive”.The closest example of this class of objects is NGC4945. This galaxy hosts a nuclear starburst and its optical spectrum is characterized by faint LINER-like emission lines associated with the starburst superwind. However, its hard X-ray spectrum has revealed the presence of a heavily obscured AGN [11]. Another clear case has been reported by [4], who detected a heavily obscured AGN in the starburst/HII

system NGC3690. We specifically define “elusive AGN” as those nuclei which do not show Seyfert-like emission lines in their optical spectra, but where a relatively luminous AGN (i.e. in the Seyfert range) is detected at other wavelengths. Although this class of AGNs clearly exist, it is not clear how common they are, nor it is clear their nature (i.e. why they are optically elusive).

We have started a program aimed at assessing the fraction of elusive AGN in the local universe and to investigate their nature. We are mostly exploiting hard X-ray data from Chandra and XMM, but also near- and mid-IR spectroscopy, to detect obscured AGNs not identified by optical spectroscopy. Preliminary results were reported in [13] and summarized here. There are about 20 elusive AGN identified so far (though not all of them can be used for statistical purposes, see [13]). Once selection effects are taken into account we estimate that elusive AGNs may be as numerous as (or even outnumber) classical, optically identified Seyfert nuclei. The estimated fraction of elusive AGNs as a function of infrared luminosity is shown in Fig.1. Obviously the statistics are still poor and more data are required to secure this result. If confirmed, an important implication would be that the overall fraction of galaxies hosting an AGN in the local universe is significantly higher than estimated previously by optical surveys. This would nicely match the recent results from the hard X-ray surveys [20][12][9], which are finding that the evolution of Seyfert nuclei peaks at much lower redshifts than quasars and probably requiring a high density of Seyferts at z=0. Note that the higher redshift counterparts of elusive AGN may be the so-called XBONGs (X-ray Bright Optically Normal Galaxies) found in the hard X-ray surveys [6].

A most interesting result of the X-ray spectra of elusive AGNs is that they are heavily absorbed and, in particular, most of them are Compton thick, i.e. absorbed by column of gas $N_H > 10^{24}$ cm^{-2}. This suggests that their elusive nature is associated with heavy obscuration. In [13] we suggested that probably in elusive AGNs the nuclear radiation source is obscured in all directions thus preventing UV photons to escape and to produce a Narrow Line Region (NLR).

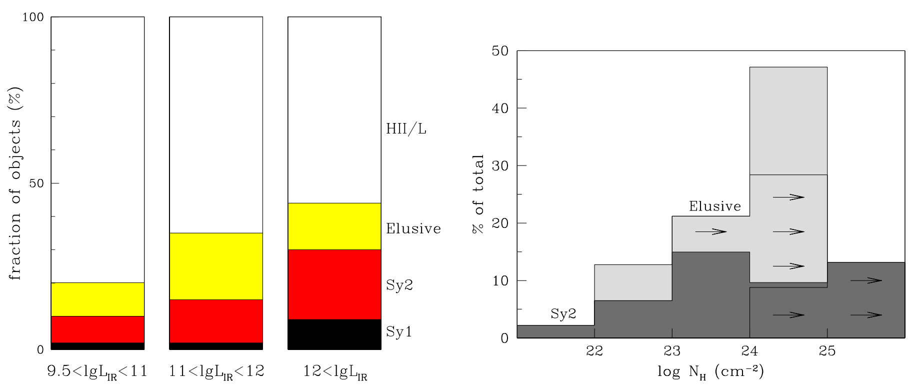

Fig. 1. *Left.* Fraction of elusive AGN and Seyfert nuclei as a function of IR luminosity. *Right.* Cumulative absorbing N_H distribution including elusive AGNs. From [13]

However, for some of the elusive AGNs other explanations are viable, such as heavy obscuration of the NLR and/or dilution by the circumnuclear starburst (which may apply to the more distant cases)[7]. An important implication of the heavy obscuration affecting elusive AGNs is that, if they are included in the local census of AGNs, then the overall distribution of absorbing N_H would be strongly skewed towards higher values with respect to what previously estimated for optically identified Seyfert 2, as shown in Fig.1.

Another interesting feature is that those elusive AGNs which were observed also in the 10–100 keV band result to be absorbed by columns in the range $10^{24} < N_H < 10^{25}$ cm^{-2}. In this case the observed X-ray spectrum is characterized by a prominent bump peaking at about 30–40 keV. If elusive AGNs are common also at higher redshift, then they could contribute significantly to the 30 keV bump of the X-ray background. Within this context, one should keep in mind that the X-ray background has been resolved at energies <10 keV, but the bulk of the X-ray background, which is produced at >10 keV, has not been resolved yet.

3 The contribution of AGNs to the infrared background

Although it is clear that most of the X-ray background is produced by a mixture of obscured and unobscured AGN (the latter dominating at higher energies), it is less clear what is their contribution to the infrared cosmic background. This is a most important issue, since the infrared is the spectral region were most of the cosmic background is produced (after the CMB) and which is expected to trace a significant fraction of the global star formation history. Dust in the circumnuclear region of AGN absorbs most of the optical-UV light emitted by the nucleus and which is reprocessed into the infrared; therefore the contribution of AGN (and in particular *obscured* AGNs) to the IR background may be significant. Some previous studies have obtained contradictory results depending on the assumed Spectral Energy Distribution (SED) and evolution of the AGNs.

We have approached the problem by minimizing the number of assumptions and by using known and measured quantities to bridge the (AGN-produced) X-ray background to the IR background. In particular, we used the AGN hard X-ray luminosity functions and evolution recently derived by [20] using a compilation of the most recent X-ray surveys. We then derived the *nuclear* infrared SED of a sample of about 30 Seyferts by using high resolution near- and mid-IR data. Such IR SEDs were then normalized to the intrinsic hard X-ray emission. Then we divided the SEDs in bins of absorbing N_H; this novel approach allows to consistently use the same method adopted for the synthesis modelling of the X-ray background. With this information we can estimate the AGN contribution to the IR background starting from the X-ray background and by essentially using only observed quantities.

Further details will be provided in a forthcoming paper [19], here we only discuss some preliminary results. Fig.2 shows the estimated fractional contribution of AGNs to the cosmic background at various infrared wavelengths. The contribution is low at all wavelengths: the maximum contribution (but still $\leq$10%)

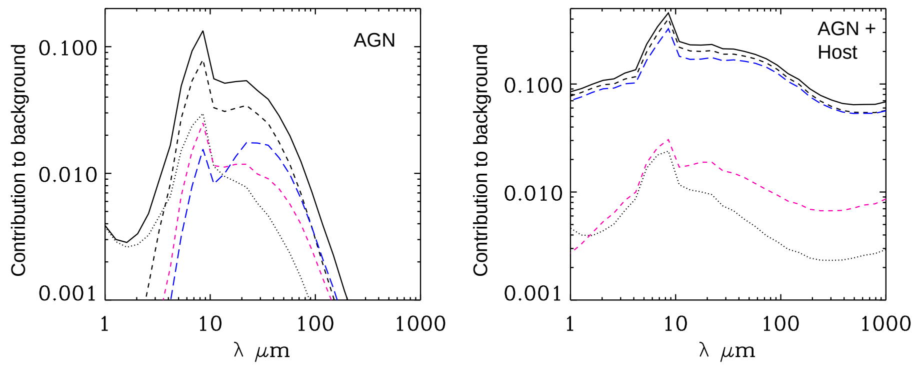

Fig. 2. *Left.* Fractional contribution of AGN to the IR background. Dotted and dashed lines show the relative contribution by AGN affected by different degrees of obscuration, while the solid line is the total contribution. *Right.* The contribution to the IR background when AGN host galaxies are also included.

is in the mid-IR, between 5μm and 40μm; while the contribution is negligible at longer wavelengths. However, AGNs are hosted in galaxies which may contribute significantly to the global infrared light emitted by these systems. If the host galaxies co-evolve with the AGN (and there are observational indications in favor of this scenario), then they could contribute significantly to the IR background. We have investigated this possibility by associating the SED of the host galaxies to the nuclear SEDs. We have then assumed that the host galaxies are linked to the AGN by the same cosmic evolution. The resulting contribution to the IR background is shown in Fig.2. AGNs and their host galaxies appear to contribute significantly to the IR background: about 20% in the mid-IR, exceeding 40% at 8μm, and ∼10% in the far-IR and sub-mm. Therefore, the cosmic IR background may have the imprint of the co-evolution of AGN and galaxies. Our results are in good agreement with the contribution at 15μm obtained by [8][1] by cross-correlating ISO and Chandra/XMM sources. Additional implications, especially for what concerns to contribution to the IR/submm source number counts will be discussed in [19].

4 Absorption and circumnuclear medium in the most distant quasars

The most distant quasars known are at a redshift (z∼6) which is approaching the epoch of reionization. At early epochs it is not obvious that the circumnuclear gas has the requirements to obscure AGNs. Indeed, obscuration in the X-rays requires that the gas metallicity has already evolved enough to provide the opacity associated to various elements, and in particular iron (whose edge is shifted into the soft X-rays). Optical and UV absorption require that dust has already been produced in large quantities at such high redshifts.

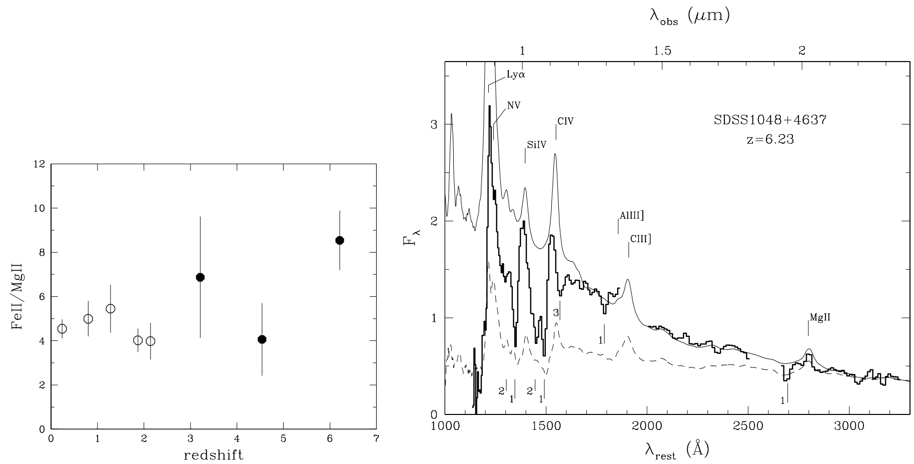

Fig. 3. *Left.* FeII/MgII observed in quasars as a function of redshift. Solid symbols at high redshift are from our survey, while open symbols at lower redshift are from [5] *Right.* The most distant LoBAL at z=6.23 found in our sample. Note the extremely deep, blueshifted CIV absorption and the associated absorptions of SIV, AlIII] and MgII. The thin solid line is the average spectrum of lower redshift non-BALs, while the dashed line is the average spectrum of lower redshift LoBAL from the SLOAN [17].

We have investigated the metallicity and absorption of the most distant quasars by means of the Near Infrared Camera Spectrometer (NICS [2]) at the Telescopio Nazionale Galileo (TNG), with its low resolution, high sensitivity IR spectroscopic mode, which allows to obtain the full near-IR spectrum from 0.8μm to 2.4μm in one shot. Thanks to the large spectral coverage and to the high sensitivity we could measure the intensity of the UV FeII-bump (redshifted into the near-IR) relative to the MgII doublet (2798Å) in a sample of 22 quasars at $3 < z < 6.4$. To a first approximation, the ratio FeII/MgII can be assumed as an indicator of the Fe abundance relative to the α elements. This is also an indicator of the age of the stellar population since α elements are predominantly produced by type II SN, while the production of Fe is delayed by type Ia SNe [16][18]. Fig.3 shows the ratio FeII/MgII in quasars as a function of redshift, indicating no decrease of the iron fraction up to z$\sim$6 (and actually there is a marginal indication for an increase of Fe). This result has two implications: 1) at the redshift of the most distant quasars known (z$\sim$6) the circumnuclear medium was already highly enriched (in particular plenty of Fe was available to provide obscuration in the X-rays); 2) the high ratio of Fe/α suggests that the hosts of the most distant quasars were formed at z>9, to allow the required time for the SN Ia to enrich the gas. Further details are given in [14].

For eight quasars at 4.9<z<6.4 our spectra include the resonant CIV line at 1549Å. Half of these quasars are characterized by deep, broad and blueshifted absorption of CIV, i.e. they belong to the class of Broad Absorption Line (BAL) quasars, which are associated with powerful outflows of dense gas. Fig.3 shows the spectrum of the most distant of these BAL quasars, characterized by a

very deep absorption of CIV and also of other high and low ionization lines (SiIV, AlIII, MgII), actually identifying this as a Low ionization BAL (LoBAL). Although the sample is small, the large fraction of BAL quasars, the depth and ionization state of the absorption features suggest that these most distant quasars are surrounded by a much larger amount of dense gas than lower redshift quasars. As discussed in [15], such a result may indicate that the highest redshift quasars are characterized by extremely high accretion rates and associated with the early formation of quasars and of their host galaxies [10].

Another interesting finding is that all these distant BAL quasars are bluer than lower redshift BALs (which are generally reddened by dust). The dashed line of Fig.3 shows the average spectrum of LoBALs at lower redshift from the SLOAN [17], which is clearly much redder than our highest redshift LoBAL (although at $\lambda_{rest} < 1500$Å there is a bending of the spectrum, partly due to the prominent absorption lines, this issue is discussed in [15]). The lack of significant reddening in the most distant BALs cannot be ascribed to lack of dust, since the presence of large amounts of dust were inferred by the submm/mm detections of these objects [3]. Therefore, these results may indicate a different extinction, and possibly reflect a different evolution and formation mechanism of dust grains at z>5. This issue will be discussed in [15]

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